RAMS 2013 Abstract Submittal:

Title *

Maximum of 70 characters

Allocating SMART Reliability and Maintainability Goals to NASA Ground Systems

Abstract Summary *

Please include a 1-2 line summary

This paper will describe the methodology used to allocate Reliability and Maintainability (R&M) goals to Ground Systems Development and Operations (GSDO) subsystems currently being designed or upgraded.

Abstract *

Please include your abstract - 1000 words or less

A methodology was developed to allocate Reliability and Maintainability (R&M) requirements to Ground Systems Development and Operations (GSDO) subsystems at the Kennedy Space Center (KSC) in Florida. This methodology presented in this paper will address the need for aggressive, yet achievable (within budget constraints), requirements for highly available ground systems in support of launch operations for both NASA and commercial customers. The methodology allows for use of historical data from previous programs, including the Space Shuttle Program (SSP), to make realistic, achievable, and improved allocations to GSDO subsystems during the design and upgrade phases of the program.

The requirement for Kennedy Space Center (KSC) Ground Systems Development and Operations (GSDO) to deliver high availability during launch operations is essential to ensure that the missions, both commercial and government, are successful. The set of Design Reference Missions (DRMs) for the Space Launch System (SLS) launch vehicle includes several Beyond Earth Orbit (BEO) missions that require launch of multiple vehicles and payloads. Viability of a multi-launch architecture is dependent on the reliability and maintainability of ground systems and the flight vehicles, particularly after the first vehicle has launched. Additionally, GSDO will need to support other 21st century launch customers who will most likely require highly available systems for launch support. The decomposition or allocation of a launch availability requirement will accomplish the GSDO goal of achieving highly available launch support systems for all potential launch customers.

For GSDO, the Launch Availability requirement can be broken into two requirements that can translate into hardware design requirements: 1) Probability of launching on a single launch attempt, and 2) Probability of being able to support repair of elements in the event of a launch scrub

requiring a rollback to the Vehicle Assembly Building (VAB) – identified as "operational availability."

Probability of launch is a function of both launch reliability and maintainability. With the introduction of a repair capability that will restore a system to an operative state, the measure of system performance is availability. The definition of inherent availability is used to allocate reliability (Mean time between failures – MTBF) and maintainability (Mean time to Repair – MTTR) values to GSDO subsystems. In this case, the failure rate (lambda = 1/MTBF) is considered to be an exponential distribution, and MTTR is considered to be lognormal distribution.

For GSDO, a failure in each subsystem could cause a hold or launch scrub during the launch countdown. Therefore, with an exponential failure rate, lambda, the reliability of GSDO for the launch countdown is the product of all subsystem reliabilities. Once GSDO's reliability goal is defined, this can be translated into lower level subsystem design goals, i.e., the GSDO level reliability requirements form the basis for establishing compatible subsystem MTBF's or reliability goals.

Subsystems Reliability allocations for probability of launch were based upon the data from prior reliability allocations and subsystem analysis that occurred during the previous program of record. Subsystems Reliability allocations for operational availability were also based upon the data from prior subsystem analyses that occurred during the previous program of record, along with repair and launch support data from the SSP.

Maintainability is the probability a failed item will be restored or repaired to a specified condition within a given period of time. In order to quantify maintainability, the repair time distribution must be defined. It is generally reasonable to assume that failure distributions are exponential; however, for the repair distribution a lognormal distribution is typically used. A significant element of Maintainability is the process of allocating system maintainability requirements to the lower subsystem levels as requirements for subsystem designs.

For GSDO, the maintainability requirement must have both a repair time (MTTR) and a probability of repair. When using a lognormal repair distribution, to determine the MTTR that a system must achieve to meet the requirement, one must first determine the median time to repair and shape parameter then solve for MTTR. For example, if a requirement states that GSDO must be repaired within 96 hours 80% of the time, assuming the repair distribution is lognormal with a shape parameter (s) of 0.45, then GSDO must achieve a MTTR of approximately 72 hours. The 72 hour MTTR would then be allocated to the subsystems per the allocation procedure described in this paper.

Once a system maintainability goal is defined, this can be translated into lower level design goals, i.e., the GSDO level maintainability requirements form the basis for establishing compatible subsystem MTTRs. One way of allocating maintainability requirements to subsystems is to weight the reliability requirement using only the failure rate. This is a good way to initially allocate maintainability if many of the characteristics of the subsystems are unknown. However, in this case, many of the repair characteristics of the GSDO subsystems are known, and, therefore, the allocation process must also consider factors such as field experience, maintainability design characteristics and the maintenance concept of each equipment item, and combine them to produce an achievable and aggressive value for maintenance (or MTTR).

Using a method described in an article from the IEEE Transactions on Aerospace and Electronic Systems entitled, "A Practical Method of Maintainability Allocation," maintainability allocations to GSDO subsystems integrated reliability, field experience, maintainability design characteristics, and the maintenance concept directly into the Maintainability allocation process by using a weighting factor (k). This method considers that failure rates are exponentially distributed and repair times are log normally distributed (which is the case for most repair times).

This paper will also describe the process used for reporting and tracking R&M requirements to management, so that they can make an informed decision regarding the use of funds to upgrade or re-design a subsystem that presents a risk to the GSDO goal of high launch availability.

Biography *
Please include a brief biography - 150 words or less

Amanda Gillespie (Author 1 & presenter) received her BS in Applied Mathematics from the Georgia Institute of Technology in 2000. She is a Reliability Engineer with SAIC at NASA KSC. Amanda is a member of the ASQ Reliability and Statistics Societies as well as a member of the Society for Reliability Engineers (SRE). Amanda received her ASQ CRE in 2011. Dr. Mark Monaghan (Author 2) received his Ph.D in Applied Decision Science from Walden University in 2008. Mark is Reliability Engineer with SAIC at NASA KSC. He is a senior member of the IEEE IAS, PES, and Reliability Societies. He is also a member of AIAA and the ASQ Reliability Societies.